Received: 21 October 2021 | Revised: 19 May 2022 | Accepted: 20 May 2022

DOI: 10.1111/pirs.12688

FULL ARTICLE

Proposition for an additional input output multiplier metric to access the value contribution of regional cluster industries

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Funding information
Engineering and Physical Sciences Research Council, Grant/Award Numbers: EP/K000446/2, EP/W005212/1; Innovate UK, Grant/Award Number: 75989

Abstract

This paper proposes a new multiplier metric to understand the value contribution of industries. We build on the conventional input output employment and income multiplier methods familiar to policy makers and academic research communities to propose a 'wage premium' multiplier that facilitates focus on the quality of employment embedded in supply chains. Here, we use the illustrative case of a key Scottish manufacturing chemicals industry. Crucially, our innovative and benchmarking approach demonstrates the potential vulnerabilities on the value contribution of key industries by identifying the interaction of higher average wages in some supply chain industries and numbers of jobs in others in delivering wage premium outcomes.

KEYWORDS
chemicals industry, input output, interindustry activity, quality of employment, wage premium

JEL CLASSIFICATION
C67, J30, L65

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1 | INTRODUCTION

As many national and regional economies have committed to transition to low carbon and net zero futures, there is a growing recognition of the need to consider political economy narratives and perspectives of key challenges such as decarbonizing emissions intensive high value industries. For example, in the UK emphasis is placed on the need to identify potential opportunities through support and promotion of competitive domestic supply chain activity, as prioritized in the UK Industrial Strategy (BEIS, 2017). This is specifically reflected in the UK carbon capture, utilization and storage (CCUS) Action Plan (BEIS, 2018), which sets out the case for supporting costly carbon capture activity in an industrial cluster context of sustaining and ultimately growing high value sectors and the jobs supported via domestic supply chain activity (BEIS, 2018).

At a devolved national/regional level, impacts on jobs and the quality of employment of potential actions and pathways to decarbonize key sectors and supply chains are central concerns of the Scottish Just Transition Commission, set up by the Scottish Government in 2019.[1] In short, a crucial question arises in how the UK Government, and devolved authorities therein, can support industrial decarbonization and the wider net zero transition in a way that unlocks benefits and delivers the type of economic prosperity valued in a wider societal context. Addressing this question is contingent on providing policy-makers with a more comprehensive and clearer picture of the current circumstance/situation regarding the extent and nature of jobs, incomes and value-added currently delivered by key industrial clusters and what the potential vulnerabilities might be as a result of policy actions.

The regional science and economics literature provide a key starting point and analytical tool in the application of multisector conventional input output analysis (Leontief, 1936; Miller & Blair, 2009). In this regard, there is an extensive literature focusing on the importance and size of the job/employment multiplier and quantifying the aggregate employment impacts of various industrial activities based on different policies for development (see for example Cameron & Van Der Zwaan, 2015; Garrett-Peltier, 2017; Henderson et al., 2017; Oliveira et al., 2013). There have also been some input output methodological developments and advancement in terms of identifying what factors and determinants may affect/limit the size of the employment multipliers. For example, where focus is on considering the current "state of an economy" vs a hypothetical state (i.e., where an industry has relocated to another region, but continues to purchase intermediate inputs (excluding labour) and inter-industrial differences in wages and productivity are used in calculating employment multipliers, Groenewold et al. (1987) and Weiss and Gooding (1970) lay key foundations.

In recent years, Allan, McGregor et al. (2007), use input output to demonstrate the economic distinctiveness emerging from effectively disaggregating sectoral activity when considering systemwide impacts and employment levels. Using the extended input output framework developed by (Leontief, 1970), Allan, Hanley et al. (2007) with further developments in Alabi et al. (2019), consider how multipliers can be used to identify price pressures throughout the economy that may manifest if the input cost of any one industry is pushed up, which has the potential to affect the size of the employment multipliers. Emonts-Holley et al. (2021) proposes alternative calculations for considering the impact of exogenous expenditure and household final demand on the size of the employment multipliers.

However, the different applications, developments and considerations of the input output employment multiplier metric can only tell us about the number of jobs or quantity of employment created or lost (i.e., based on direct, indirect, and induced effects) and cannot tell us about the quality of employment/jobs, particularly from a policy perspective on the extent to which the jobs can be considered as "high-quality" jobs. In policy-facing research, Turner, Alabi, et al. (2018) used employment multiplier metrics to inform policy strategy and building consensus around a policy narrative (e.g., Turner, Race, et al., 2018 is cited by the CCUS Cost Challenge Task Force, 2018, and subsequently the BEIS CCUS Action Plan, 2018). These works focused on understanding the socio-economic value embodied in industry supply chains in terms of jobs supported. Here we make a first attempt to shift attention to the

[1]The terms of reference and objective of the Scottish Just Transition Commission is available at https://www.gov.scot/groups/just-transition-commission/

wage incomes (earnings) associated with direct and indirect employment requirements to consider the quality of employment. While there are a number of ways and characteristics to considering the quality of employment (see for example Burchell et al., 2014; De Bustillo et al., 2011; Piasna et al., 2020), the wage income associated with jobs is of fundamental importance to policy decision-makers concerned with sustaining gross domestic product (GDP) and the tax base.

Here, we make a policy-relevant contribution by using input output analysis to demonstrate how the supply chain multiplier mechanisms can be adapted to focus on employment incomes associated with jobs supported by key industries. This is motivated by the fact that such multiplier innovation can play a key role as an additional benchmarking metric/tool and precursor to provide insights around pre-identifying the potential vulnerabilities on the value contribution of industries that have historically been and will continue to be important to regional and the national economic base. We illustrate this with focus on three industries within the Scottish chemicals sector. In doing so, we demonstrate how the conventional employment and wage income multiplier metrics can be augmented by combining underpinning information in a supported wage multiplier. This reflects the wage premium provided to the economy relative to the average national/regional wage.

Subsequent sections are structured as follows. In Section 2, we offer a step-by-step explanation of how we extend the conventional input output economic multiplier analysis to derive a new metric that reports the quality of employment in terms of average wage supported. Results (using the 2015 IO tables published by Scottish Government) are presented and discussed in Section 3. Our conclusions and the policy implication of our methodology development and analyses are discussed in Section 4 with future research direction in Section 5.

2 | APPLICATION OF A NEW MULTI SECTOR INPUT OUTPUT MULTIPLIER METHOD

Conventional input output multiplier analysis (Leontief, 1936; Miller & Blair, 2009) is a core tool commonly and frequently used by both regional and national economies in understanding the role and contribution of a single industry and interrelated economic activity.[2,3] In this section, we demonstrate and outline how the conventional or original input output framework (Leontief, 1936; Miller & Blair, 2009) may be developed for enhanced value chain multiplier analysis and the reporting of high impact metrics on the quality of employment. Using regional accounting industry-by-industry input output tables, the most straightforward way to consider the quality of employment in a direct sector context is to calculate the average wage for any one industry. This can be achieved by dividing the total income from employment (compensation for employment) for any one industry reported in the input output table for a given accounting year, Y, by the corresponding number of employees (FTE jobs) for that industry, E. Thus, a direct measure of average wage is expressed as, $\frac{Y}{E}$. However, calculating the average wage in this way does not fully exploit the power of the input output framework, and is insufficient if interest lies in understanding the implications of the full supply chain requirements, the interdependence of sectors in the economy and the impact on both jobs and earnings. Rather, we can further exploit regional or national accounting industry-by-industry input output data and methods or framework to consider how average wages—the key measure of the value associated with jobs—in different sectors and across the wider economy are a function of the integrated and interdependent nature of supply chain activity.

As is generally the case, the core foundation of the new multiplier metric we propose here is the basic input output identify (Leontief, 1936; Miller & Blair, 2009):

[2]The Scottish Government input output statistics and routine exercise of input output multiplier analysis is available at https://www.gov.scot/publications/input-output-latest/

[3]The Welsh Government in consultation with Welsh Economy Research Unit, publish annual economic review that are informed by input output multiplier analysis available at https://wer.cardiffuniversitypress.org/

$$\mathbf{x} = (\mathrm{I} - \mathrm{A})^{-1} \boldsymbol{f}, \tag{1}$$

where **x** is a (N × 1) column vector of gross output by industry and ***f*** is the (N × 1) final demand vector. The $(\mathrm{I} - \mathbf{A})^{-1}$ matrix is the Type 1 Leontief inverse or output multiplier matrix[4] denoted here as **L**. Thus, we can restate Equation (1) as follows:

$$\mathbf{x} = \boldsymbol{Lf}. \tag{2}$$

Equation (2) tells us the total output required across the economy to support the final demand for any one commodity output. Generally, matrix **L** informs on the distribution of activity supported in the economy and the elements within the matrix, l_{ij}, gives the output in sector i directly or indirectly required to produce one unit of final demand in sector j. This allows for analytical consideration and examination of other variables of interest embedded in supply chain activity supporting the demand for any one activity in the economy. Thus, if we want to consider, for example income or employment, then the output income multiplier, **y** can be generated as follows:

$$\mathbf{y} = \boldsymbol{yLf}, \tag{3}$$

where **y** on the right-hand side of the Equation (3) is an 1 × N vector of income (compensation for employment), where each element, y_j is given by dividing total income in industry i by that industry's total output, x_i. Similarly, drawing on external (to the input output table) full-time equivalent (FTE) employment data, the N × N output employment multiplier can be represented as follows:

$$\mathbf{e} = \mathbf{e}\boldsymbol{Lf}. \tag{4}$$

In 4, variable **e** on the right-hand side denotes a 1 × N vector of employment coefficients, calculated by dividing total FTE jobs in industry i by that industry's total output, x_i.

Equations (3) and (4) are the conventional income and employment multipliers. However, to consider the full supply chain requirements and mechanism that underpin the value chain in the economy though the income and employment multipliers, we introduce diagonal matrices in place of the vectors. Such that Equations (3) and (4) are restated in matrix form as follows:

$$\mathbf{Y}_{\boldsymbol{\upsilon}} = \begin{bmatrix} y_{\upsilon 1} l_{11} f_1 & y_{\upsilon 1} l_{1j} f_j & \ldots \; y_{\upsilon 1} l_{1n} f_n \\ y_{\upsilon i} l_{i1} f_1 & y_{\upsilon i} l_{ij} f_j & \ldots \; y_{\upsilon i} l_{in} f_n \\ \vdots & \vdots & \ddots \; \vdots \\ y_{\upsilon n} l_{n1} f_1 & y_{\upsilon n} l_{nj} f_j & \cdots \; y_{\upsilon} l_{nn} f_n \end{bmatrix}. \tag{5}$$

Equation (5) represents the supported income matrix. Each element on the main diagonal denotes the income from employment, $y_{\upsilon i}$, required to produce one monetary unit of output in industry j. The full matrix definition of the conventional output income multiplier is determined by pre multiplying the matrix $\mathbf{Y}_{\boldsymbol{\upsilon}}$, by the output multiplier matrix in 1. Crucial for our purposes is that the vector of the column totals of $\mathbf{Y}_{\boldsymbol{\upsilon}}$, that is, $.\sum_j y_{\upsilon i} l_{ij} f_j$, gives us the total (direct and indirect) supply chain income supported by the demand for the output of industry j. Similarly, the N × N supported employment multiplier matrix, $\mathbf{E}_{\boldsymbol{\varepsilon}}$, is given by:

[4]Type II variant of the output multiplier matrix includes the additional and induced impacts of household consumption. For example, see Alabi et al. (2019), Allan, Hanley, et al. (2007), and Emonts-Holley et al. (2021).

$$\mathbf{E}_{\varepsilon}=\begin{bmatrix} e_{\varepsilon 1}l_{11}f_1 & e_{\varepsilon 1}l_{1j}f_j & \dots & e_{\varepsilon 1}l_{1n}f_n \\ e_{\varepsilon i}b_{i1}f_i & e_{\varepsilon i}l_{ij}f_j & \dots & e_{\varepsilon i}l_{in}f_n \\ \vdots & \vdots & \ddots & \vdots \\ e_{\varepsilon n}l_{n1}f_l & e_{\epsilon n}l_{nj}f_j & \cdots & e_{\varepsilon n}l_{nn}f_n \end{bmatrix}. \tag{6}$$

The sum of each column of Equation (6), (i.e., $\sum_i e_{\varepsilon i}b_{ij}f_j$) gives us the number of FTE jobs supported across the economy from the final demand for the output of industry *j*.

The simplest route to deriving the supported average wage multiplier is to divide the column total of the supported income matrix (i.e., $\sum_i y_{\upsilon i}l_{ij}f_j$) by column total of the supported employment matrix (i.e., $\sum_i e_{\varepsilon i}l_{ij}f_j$). However, to understand the composition of the supported wage multiplier, three steps are required. First, given that $\mathbf{Y}_{\upsilon}$ (5) and $\mathbf{E}_{\varepsilon}$ (6) matrices share a common foundation in the Leontief inverse, **L**, and the diagonal matrix of final demand, ***f***, we can divide each *j*th element in $\mathbf{Y}_{\upsilon}$ by the corresponding *j*th element in the $\mathbf{E}_{\varepsilon}$ matrix, which may be expressed as $\frac{y_{\upsilon i}l_{ij}f_j}{e_{\varepsilon i}l_{ij}f_j}$. This will result in a matrix of underlying average sectoral wages, **W:**

$$\mathbf{W}=\begin{bmatrix} w_{11} & w_{1j} & \dots & w_{1n} \\ w_{i1} & w_{ij} & \dots & w_{in} \\ \vdots & \vdots & \ddots & \vdots \\ w_{n1} & w_{nj} & \cdots & w_{nn} \end{bmatrix}. \tag{7}$$

Note that all elements along each row of (7) will be equivalent to the average wage generated across the economy by each industry *j*. In order to understand how these, contribute to the supported average wage multiplier, a second step is required. This involves determining the employment shares that underpin matrix $\mathbf{E}_{\varepsilon}$ (6) through the introduction of a matrix $\mathbf{E}_{\mathbf{s}}$:

$$\mathbf{E}_{\mathbf{s}}=\begin{bmatrix} e_{s11} & e_{s1j} & \dots & e_{s1n} \\ e_{si1} & e_{sij} & \dots & e_{sin} \\ \vdots & \vdots & \ddots & \vdots \\ e_{sn1} & e_{snj} & \cdots & e_{snn} \end{bmatrix}. \tag{8}$$

Essentially, matrix $\mathbf{E}_{\mathbf{s}}$ is derived by dividing each element of the supported employment matrix $\mathbf{E}_{\varepsilon}$ in (6) by the corresponding column total, to determine the employment share of each industry *j*, which may be expressed as $\frac{e_{\varepsilon i}l_{ij}f_j}{\sum_i e_{\varepsilon i}l_{ij}f_j}$. Note that the column totals of matrix $\mathbf{E}_{\mathbf{s}}$, will be unitary (i.e., $\sum_i e_{sij}=1$). By introducing Equation (8) it is then possible to consider the composition of the of the supported average wage matrix generated across the wider economy for each industry *j*.

The third and final step is to apply the weights in (8) to the wage matrix in (7). That is, we pre-multiply the main diagonal of the Equation (7) by employment share matrix in (8) to derive matrix $\mathbf{W}_{\boldsymbol{\omega}}$ in (9):

$$\mathbf{W}_{\boldsymbol{\omega}}=\begin{bmatrix} w_{\omega 11} & w_{\omega 1j} & \dots & w_{\omega 1n} \\ w_{\omega i1} & w_{\omega ij} & \dots & w_{\omega in} \\ \vdots & \vdots & \ddots & \vdots \\ w_{\omega n1} & w_{\omega nj} & \cdots & w_{\omega nn} \end{bmatrix}. \tag{9}$$

The column totals of matrix $\mathbf{W}_{\boldsymbol{\omega}}$ (i.e. $\sum_i w_{\omega ij}$), represents the new metric we identify as the supported average wage, or wage premium multiplier generated across the wider economy by each industry *j*. We can confirm the formulation in (9), if $\sum_i w_{\omega ij} = \frac{\sum_i y_{\upsilon i} l_{ij} f_j}{\sum_i e_{\epsilon i} b_{ij} f_j}$, which is equivalent to the higher level route of dividing the column total of the supported income matrix (i.e. $\sum_i y_{\upsilon i} l_{ij} f_j$) in Equation (5) by column total of the supported employment matrix (i.e. $\sum_i e_{\epsilon i} b_{ij} f_j$) in Equation (6). However, the fuller formulation in (9) allows us to consider how the wage premium emerges in applied cases, such as our Scottish chemicals example below and for any other industry in the economy.

3 | RESULTS AND DISCUSSION

In this section, we discuss the results and findings that emerge from employing the new supported average wage multiplier or wage premium multiplier presented in the method section. Consider that while an industry may support more or less FTE jobs—which is important in its own right—we are concerned here with the quality of jobs (employment) to identify the real source of economic value. In this context, it common to consider income multipliers as well. However, this also on its own cannot give us the wage premium. We illustrate what further insight and information on the supply and associated value chain we get out of the new input output multiplier metric in comparison or relative to the conventional input output multipliers.

3.1 | A conventional analysis

In Table 1 we report the convention output, employment, and income multipliers (Type I) for the three main industries within the Scottish chemicals sector: "petroleum refining and petrochemicals" (SIC 19 and SIC 20B), "inorganic chemicals" (SIC 20.5) and "other chemicals" (SIC 20 AC) based on Scottish industry-by-industry input output data for the accounting year 2015. All the results columns in Table 1 are computed using Equations (1), (3) and (4) respectively. In considering the conventional multipliers of the Scottish chemical sectors a first observation is how these industries rank in comparison to all $\mathbf{N} = 98$ industries reported in the regional input output data for the accounting year 2015.

Let us begin with the output multipliers. Across all Scottish industries, the electricity industry ranks highest at 1.87. This tell us that for every £1million demand for the electricity sector's output, a further 870 k is generated throughout the economy due to indirect supply chain effects. The size of the electricity industry's output multiplier reflects the strength of its domestic supply chain, which is dominated by reliance on Scottish service sectors. Aquaculture (1.77) and forest harvesting (1.72) have the second and third highest output multipliers. The picture is very

TABLE 1 Output multipliers values for the Scottish chemicals sector

SIC	Sector name	Output multipliers (£ million)	Rank	Output employment multipliers (FTE jobs)	Rank	Output income multiplier (£ million)	Rank
19, 20B	Petroleum refining and petrochemicals	1.30	47	3.57	94	0.29	78
20.5	Other chemicals	1.24	72	5.75	84	0.33	71
20 AC	Inorganic chemicals	1.31	46	5.25	90	0.39	55

different for the Scottish chemicals sectors. One issue to note is that, for disclosure (firm ownership) reasons, the Scottish input output tables have to aggregate across petroleum refining and petrochemicals. We observe that inorganic chemicals and petroleum refining and petrochemicals rank together at 46th and 47th respectively but have higher output multiplier values compared to that for the other chemicals industry, which ranks 72nd. This may be attributed to, '"other chemicals" having a higher share (63.51%) of its immediate inputs from imports (this breaks into 35.72% from the rest of the UK, RUK, and 27.79% from overseas or rest of the world, ROW).

The next question, given our focus, is how the Scottish chemicals sectors rank on employment and income. First, we consider the output employment multipliers (full-time equivalent, FTE, jobs per £1 m of final demand). The top three industries in Scotland with the highest employment multipliers are security and investigation (46.37 FTE), building and landscape services (30.16 FTE) and education (26.57 FTE). This reflects the fact that these are high labour-intensive service sectors in the Scottish economy. In the case of the chemicals sectors, all three have smaller employment multipliers, and in fact fall in the rankings of 84th or below. This also reflects the fact that all three chemical industries are capital intensive, and more so petroleum refining and petrochemicals.

However, that an industry has a low labour intensity does not necessary translate directly to a low wage intensity. Table 1 also reports the Type 1 (wage) income multipliers. In terms of Scotland-wide rankings, the largest income multipliers emerge from the domestic supply chain requirements of Scottish service sectors, with education (0.70), membership organizations (0.65) and residential care and social works (0,62) ranking top three respectively. In Table 1, inorganic chemicals has the strongest output income multiplier within the Scottish chemicals sector, though only recovering its ranking (relative to the employment multiplier) to 55th in the wider economy, with £390 K in wage income generated across the economy per £1million of spending on inorganic chemicals.

We can decompose these high-level multipliers and their scale impacts to better understand the direct and indirect effects. For example, how does the pattern of the rankings for the Scottish chemicals sectors change if, for example, we are concerned with how many jobs/how much income are contained in the indirect supply chain only (i.e., because higher level input output and other statistics can tell us about the industry itself)?

We investigate this by decomposing the results reported in Tables 2 and 3 and introducing the scale of activity driven by final demand for industry output, through computation and examination of the columns of the $\mathbf{Y}_{\mathfrak{v}}$ (i.e., Equation 5) and $\mathbf{E}_{\epsilon}$ (i.e., Equation 6) matrices. In terms of the former (i.e., focusing on the absolute wage income value of supported employment), if we strip out the own-sector element, the three industries with the highest indirectly supported income are in public administration (£1506.69 m), construction (£1103.77 m) and health respectively (£795.13 m). A key result emerging in the case of the Scottish chemicals sector is that petroleum refining and petrochemical moves up the chart to 41st position, indirectly supporting £77.17 m in income. See Table 3: it supports more wage income across the economy than either other chemicals (£21.35 m) and inorganic chemicals (£13.05 m), both of which rank higher on the output-income multiplier in Table 1. Again, given that the own sector element is stripped out, this suggests that the upstream supply chain of the petroleum refining and petrochemical sector is dominated by high labour and/or wage intensive service industries, with its level of activity pulling the total

TABLE 2 Income multiplier characteristics of the Scottish chemicals sector

SIC	Sector name	Direct supported income (£million)	Rank	Indirect supported income (£million)	Rank	Total supported income (£million)	Rank
19, 20B	Petroleum refining and petrochemicals	281.38	39	77.17	41	358.55	42
20.5	Other chemicals	107.43	68	21.35	72	128.78	72
20 AC	Inorganic chemicals	72.12	75	13.05	86	85.17	79

TABLE 3 Employment multiplier characteristics of the Scottish chemicals sector

SIC	Sector name	Direct supported employment (FTE jobs)	Rank	Indirect supported employment (FTE jobs)	Rank	Total supported employment (FTE jobs)	Rank
19, 20B	Petroleum refining and petrochemicals	2,376	74	2020	43	4,396	65
20.5	Other chemicals	1,682	80	560	78	2,242	81
20 AC	Inorganic chemicals	799	89	360	86	1,158	91

supported income up relative to its multiplier intensity, and those of the other chemicals sector. Although not explicitly reported here (due to space constraints), underlying this result is that income supported in the distribution sector which constitutes 25% of the total, with other Scottish services sectors accounting for 24% of the total indirect supported wage income supported by the petroleum refining and petrochemicals industry.

Further insight is gained by generating the associated indirect employment results. Table 3 reports the employment characteristics of the Scottish chemicals sectors. The Scottish sectors with the most indirect employment supported in their supply chains are public administration (49,942 FTE jobs), construction (32,543 FTE jobs) and health (25,214 FTE jobs). These are labour intensive service and distribution industries. In the case of Scottish chemicals sectors, the total employment indirectly supported in supply chains remains limited relative to these top-ranking sectors. The crucial shift is among the chemicals sectors, and again relating to the scale of activity supported by petroleum refining and petrochemicals, which supports 2020 indirect jobs, ranking 43rd of all Scottish sectors. This compares to other chemicals and inorganic chemicals, which respectively support 560 and 360 indirect jobs, with rankings down in the 70s and 80s.

However, this analysis is limited, and somewhat fragmented in considering the wage value measure of quality of jobs. Examination of supported employment and wage income metrics, and the associated multipliers, rankings, etc. does not get us directly to the question of whether direct and indirectly supported jobs can, on average at least, be considered as good quality/high value jobs. Thus, the next question emerging focuses on how the pattern of the results and rankings for the Scottish chemical sectors change when we consider supported income and employment multiplier information combined through our new supported average wage, or wage premium, matrix and how sector metrics in this regard compare to the Scottish average wage.

3.2 | A new multiplier metric: supported average wage or wage premium multiplier analysis

Thus, the question we now address is the extent to which the Scottish chemicals sector may be consider as providing and supporting high quality employment, as measured by the average wage supported across the wider economy by the Scottish chemicals sector activity. Table 4 reports the supported average wage, and wage premium characteristics of the Scottish chemicals sectors computed using $\mathbf{W}_\omega$ (Equation 9). In terms of average wage supported across the wider economy this is dominated by the domestic supply chain of Scottish manufacturing and chemical sectors, with pharmaceuticals (£89,499), petroleum refining and petrochemicals (£81,558) and inorganic chemicals (£73,532) ranking as the top three across all Scottish industries. However, we know, from the input output data, that the own sector average wage is high in all of these cases. If interests lie in the quality of supported employment, we can use $\mathbf{W}_\omega$ as defined in Equation (9) to strip out the own sector wage and focus on the indirectly supported average wage.

If we do this, other sectors take over the top spots, with fishing (£39,765), other metals and casting (£39,447) and wearing apparel (£39,439) ranking 1st to 3rd position respectively, with the largest premiums over the Scottish average (£32,225). However, two of the chemicals' industries still fall within top ten range, with petroleum refining and petrochemicals and other chemicals respectively supporting indirect average wages of £38,206 and £38,123, with premiums of just under £6 k per annum over the Scottish average. Inorganic chemicals ranks lower but still supports a substantial £4 k premium. Figure 1 reports comparable total and indirect supported average wage results for a wider range of Scottish sectors, ranking by the higher-level figure.

TABLE 4 Average wage supported and wage premium characteristics of the Scottish chemicals sector

SIC	Sectors	Average wage supported	Rank	Average wage supported (excluding own sector)	Rank	Wage premium	Rank
19, 20B	Petroleum, refining and petrochemicals	£81,558	2	£38,206	9	£5,951	9
20.5	Other chemicals	£57,452	7	£38,123	10	£5,869	10
20 AC	Inorganic chemicals	£73,532	3	£36,307	20	£4,052	20

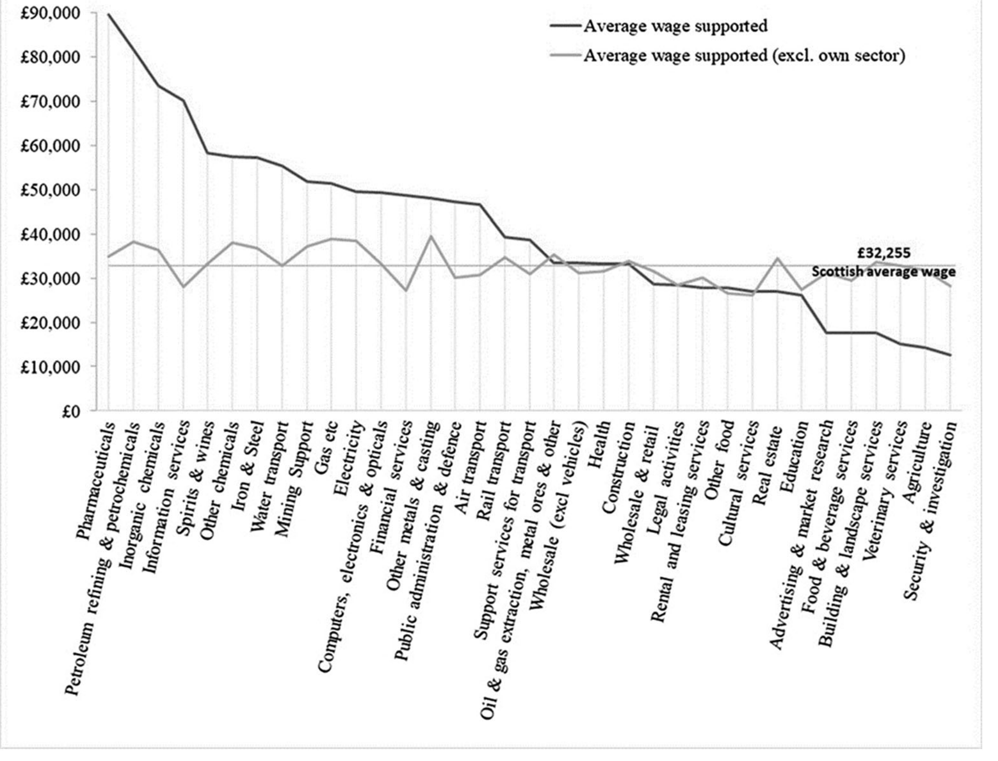


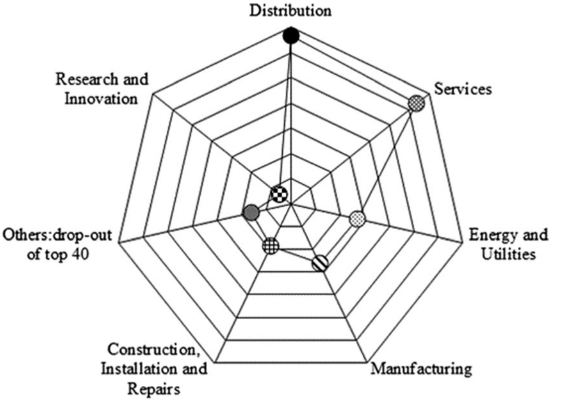
FIGURE 1 The wage premium multipliers: average wage supported across all Scottish sectors by activity in selected Scottish industries

3.3 | Composition and breakdown of the value chain of Scottish chemicals sector

What are the sources and/or enablers or drivers of these average supported wage premiums associated with the Scottish chemicals sectors? Let us consider and examine the supported average wage of the Scottish chemicals sectors (using the illustrative case of petroleum refining and petrochemicals) in the context of supported employment, where the latter tells us the total (direct plus indirect) FTE number of workers, or just those in the supply chain (the indirect component). The link to employment numbers is important as it can tell us just how important the different elements of the supported average wage are in delivering value to the economy; that is, linking to what we do analytically with employment weights in Equation (8).

Figure 2 breaks down the composition or sectoral location of the total indirect supply chain employment supported by demand for the output of the Scottish petroleum refining and petrochemicals industry derived using columns of $\mathbf{E}_\varepsilon$ (i.e., Equation 6). The accompanying table section details the breakdown of the supported average wage in each of these groups (which, in turn, is determined by just what activities are required in each case). That is, we examine the columns of $\mathbf{W}_\omega$. For simplicity we categorize the supply chain jobs into six core economic activity groups that represent the top 40 sectors (out of $\mathbf{N} = 98$ sectors) where the most indirect supported upstream jobs are located and ranked from highest to lowest (i.e., reading clockwise). The seventh group 'others: drop-out of top 40 group' denotes the sectors that did not make top 40 and comprises of a mix of sectors across all the economic activity groups.

The first feature to note in Figure 2 and the accompanying table (where the sectors identified in Figure 2 are groupings of our input output industries) is the patterns and spread of the FTE jobs within the supply chain of the Scottish petroleum refining and petrochemicals industry. These jobs are mainly concentrated in the "distribution", "services" and "energy and utilities" respectively. A total of 600 FTE jobs are supported in distribution (30% of the total supported indirect jobs and 14% overall), a further 574 (28%/13%) in services, and 246 in energy and utilities (12%/6%). Note that the smaller numbers employed in energy and utilities is associated with a relatively high average



Industry grouping	Breakdown of composition of supply chain jobs	Rank	Average wage	Rank
Distribution	600	1	£32,007	6
Services	574	2	£32,528	5
Energy and Utilities	246	3	£55,321	1
Manufacturing	236	4	£50,009	2
Construction, Installation and Repairs	166	5	£38,626	4
Others: drop out of top 40	144	6	£42,052	3
Research and Innovation	54	7	£26,213	7

FIGURE 2 Composition of total supported upstream indirect employment supplied by the Scottish 'petroleum refining and petrochemicals' industry

wage. This is one reflection of the quality of albeit more limited employment (associated with the type of skill requirements and reliance required within the petroleum refining and petrochemicals supply chain) that increases the value contributed to the supported average wage and wage premium. The distribution group comprises of sectors such as "'wholesale & retail" and "transport" and "'transport services" (including land and non-land transports). Service includes sectors such as "financial services," "legal activities" and "public administration." Distribution is an example where a relatively high employment share interacts with some lower average wage sectors in delivering the overall value contribution to the supported average wage and wage premium associated with petroleum refining and petrochemicals.

The second feature to note is the change in ranking of the economic activity groups in comparison to the composition of supply chain jobs if we move between supported employment and the associated underlying wage level. Distribution drops from 1st on employment to 6th position on average wage. On the other hand, energy and utilities moves from 3rd to 1st based on the average wage of over £55 K.

Equation (9) allows us to more formally—consider the relative importance of supported employment (quantity) and underlying wage (value) in contributing to the supported average wage and wage premium as reported in Table 4 and Figure 1. For example, if we focus on petroleum refining and petrochemicals and the variant where we exclude the own sector effect. In terms of the contribution of jobs supported in distribution the employment share, from above (and aggregating across for all sectors, notated by *i*, included in that grouping) is 30%. If we then multiply this share by the (grouped distribution) sector average wage of £32,007, we have a value of £9,505 that equates to 25% of the total supported indirect average wage. The same calculation for the grouped Services sector, (28% times £32,526) gives a value of £9,243, which is equivalent to 15% of the total supported indirect average wage. Energy and utilities (12% times £55,321) gives a value of £6,729, equating to 18% of the total supported indirect average wage. Thus, Equation (9) allows us to determine that distribution makes a larger contribution to the overall supported average wage and wage premium delivered by the petroleum refining and petrochemicals than services or energy and utilities. It is this type of result that examination of separate income and employment multipliers cannot inform on but can be considered using our proposed supported average wage multiplier method and metric.

A third and crucial point to note is that, while analysis of the type presented here could be conducted at sector level if appropriate input output data were available; the usefulness of doing so may be limited, at least in our applied Scottish example. That is, the supply chains that enable, and are enabled by, the presence of high value petroleum refining and petrochemicals activity, have a much broader economic spread across the Scottish economy, including a range of service, utility, and other manufacturing sectors. Although not presented in the main text, the supply chain activity in other chemicals and inorganic chemicals are also dominated by jobs in Scottish distribution, services, and manufacturing sectors (see Figures A1 and A2 in the Appendix for more details). These supporting sectors have a limited presence, if any, at the main Scottish industry cluster at Grangemouth, in the Eastern Central Belt of Scotland, or at any other cluster in the regional economy. Outcomes such as these emphasize that a focus on geographical clusters may be somewhat misdirected in considering the contribution of sectors like Scottish chemicals to the wider economy. For example, the UK Government CCUS Action Plan (BEIS, 2018) does focus on the need to decarbonize and sustain high value geographical industry clusters but, in doing so, refers to supported jobs that are more widely spread across the UK national and regional economies.

4 | CONCLUSIONS AND POLICY IMPLICATION

In this paper, we address questions around the extent to which the manufacturing industry like the Scottish chemicals sector may be considered as providing high quality employment to its host economy. We do so through the introduction of a new input output multiplier metric. In general, our analysis presented here is a first attempt to illustrate how conventional input output multiplier methods may be extended to communicate the fuller integrated and interdependent nature of activity that constitute the real source of economic value associated with employment.

Specifically, we focus attention on the fuller value chain in a region that may be impacted, but ultimately needs to be sustained through deployment of any pathways considered in addressing for example the decarbonization and the net zero challenge and priorities at hand.

Through our analysis, we show the unanticipated importance of the Scottish service sectors linkages in delivering value in economic expansion through job creation. We have also shown that employment numbers supported through the Scottish petroleum refining and petrochemicals supply chain are dominated by jobs in lower wage distribution and service sectors, while energy/utilities and other manufacturing are critical contributors to the value of jobs supported by this important Scottish industrial activity. Our wage premium multiplier reveals that these employment and income effects combine to determine the relatively high average wage supported by the industry's supply chain activity.

The type of policy-facing insight and implication that may more generically emerge from application of our new input output multiplier approach are in terms of how the contribution of different activities may be considered by regional and national policy actors and regulators. More specifically, our proposed supported average wage multiplier (and associated wage premium enables initial analysis of any action (decarbonization or otherwise) that is likely to impact the activity of particular industries (such as Scottish chemicals) that will ultimately be impacted through that sector's supply chain and the value of employment supported by it.

5 | FUTURE RESEARCH DIRECTION

Crucially, our approach lays the foundations for application of more flexible economy wide computable general equilibrium (CGE) modelling framework (see for example, Gillespie et al., 2001; McGregor et al., 1996; Turner et al., 2012) for regional applications and (see for example Babatunde et al., 2017; Partridge & Rickman, 2010; Turner et al., 2021) for other applications. CGE models are widely used by both government departments/ministries such as HM Treasury and economic researchers, due to its capacity to incorporate a full range of market operations and fiscal pathways, while retaining the key structural features of input output. Essentially, moving to the CGE model will permit consideration of "what if" scenarios and the ripple effects of a change in any one sector (e.g., Scottish chemicals sector) across all areas of the economy. For instance, investigating questions such as, how might activity levels, prices, incomes and associated employment across different markets and sectors be impacted, by actions to reduce emissions in energy-intensive industries? In this context, there is also a crucial need to consider who ultimately bears the costs.

Nonetheless, we believe that the new input output multiplier metric we develop here is a crucial and essential first step that can provide key insights in circumstances and situations where the activity of industries is going to have to change and/or clusters or cluster industries need to adapt. For instance, or most obviously due to decarbonization and the net zero context. This lays the foundations for developing a better understanding on how the introduction of decarbonization and uptake of other low carbon solutions may impact across all sectors of the wider economy, set in the context of outcomes that effect government and political decision-making, and the societal acceptance (or not) of those solutions.

ACKNOWLEDGEMENTS

The research reported here has been supported through various projects: EPRSC Grant refs: EP/K000446/2; EP/W005212/1; Innovate UK (Grant ref: 75989). Karen Turner also acknowledges the support of the Research Council of Norway via the PLATON project led by CICERO, Oslo. The data that support the findings of this study are openly available at Scottish Government website on Supply, Use and Input output Tables at https://www.gov.scot/publications/input-output-latest/.

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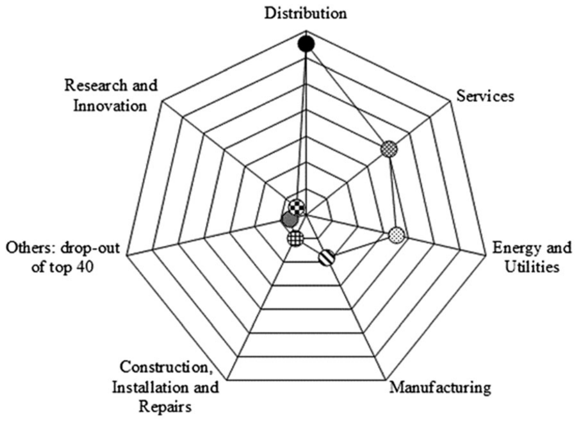
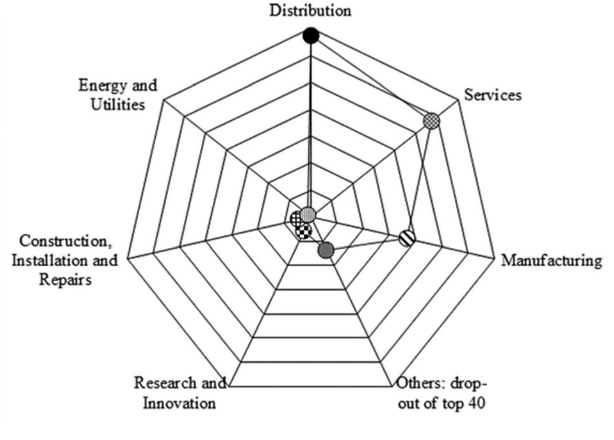
How to cite this article: Alabi, O., Turner, K., Race, J., & Katris, A. (2022). Proposition for an additional input output multiplier metric to access the value contribution of regional cluster industries. *Papers in Regional Science*, 1–15. https://doi.org/10.1111/pirs.12688

APPENDIX A



Industry grouping	Breakdown of composition of supply chain jobs	Rank	Average wage	Rank
Distribution	130	1	£32,082	6
Services	80	2	£32,887	5
Energy and Utilities	70	3	£56,625	1
Manufacturing	36	4	£35,038	4
Construction, Installation and Repairs	20	5	£38,795	3
Others: drop-out from top 40	13	6	£44,910	2
Research and Innovation	10	7	£17,967	7

FIGURE A1 Composition of total supported upstream indirect employment supplied by the Scottish 'Inorganic Chemicals' industry



Industry grouping	Breakdown of composition of supply chain jobs	Rank	Average wage	Rank
Distribution	202	1	£31,810	6
Services	172	2	£36,577	5
Manufacturing	110	3	£50,914	2
Others: drop-out of top 40	41	4	£40,501	4
Research and Innovation	18	5	£27,123	7
Construction, Installation and Repairs	14	6	£41,218	3
Energy and Utilities	4	7	£57,461	1

FIGURE A2 Composition of total supported upstream indirect employment supplied by the Scottish 'Other Chemicals' industry